no action req'd
OHL

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: 9/15/77

Project Title: Electromagnetic Environmental Survey.

Project No: A-2054

Project Director: B. M. Jenkins

Sponsor: ITEL Corporation, Atlanta, GA

Agreement Period: From 9/8/77 Until 9/29/77

Type Agreement: Standard Industrial Research Agreement dated 9/8/77

Amount: $3,000

Reports Required: Final Report

Sponsor Contact Person (s):

Technical Matters

Contractual Matters
(thru OCA)

Mr. Alan P. Cade
ITEL Corporation, Bldg. One
Suite 204
5825 Glenridge Drive
Atlanta, GA 30328

Defense Priority Rating: N/A

Assigned to: Electronic Technology Laboratory (School/Laboratory)

COPIES TO:

Project Director	Library, Technical Reports Section
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Reports Coordinator (OCA) ✓	

no action
OCA

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GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: October 17, 1977

Project Title: *Electromagnetic Environmental Survey*

Project No: A-2054

Project Director: B. M. Jenkins

Sponsor: ITEL Corporation, Atlanta, Ga.

Effective Termination Date: 9/29/77

Clearance of Accounting Charges: 9/29/77

Grant/Contract Closeout Actions Remaining:

- X Final Invoice ~~and Closing Documents~~
- _ Final Fiscal Report
- _ Final Report of Inventions
- _ Govt. Property Inventory & Related Certificate
- _ Classified Material Certificate
- _ Other ____________

Assigned to: Electronics Technology Laboratory (School/Laboratory)

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Other ____________

CA-4 (3/76)

A-2054
Final Letter Report

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

October 3, 1977

Mr. Alan P. Cade
ITEL Corporation
Building One, Suite 204
5825 Glenridge Drive
Atlanta, Georgia 30328

Dear Mr. Cade,

Attached is a letter report describing the electromagnetic survey evaluations conducted under our Industrial Research Project Agreement dated 8 September 1977.

It has been our pleasure to work with you and ITEL Corporation, and we appreciate the opportunity to be of service.

Sincerely,

B. M. Jenkins
Project Director

BMJ/slb

ELECTROMAGNETIC ENVIRONMENTAL SURVEY

ITEL CPU Location
21st Floor
Life of Georgia Building
Atlanta, Georgia

Conducted for
ITEL CORPORATION
on September 8-9, 1977

B. M. Jenkins
ENGINEERING EXPERIMENT STATION
Georgia Institute of Technology
Atlanta, Georgia 30332

1. Introduction

Mr. Alan P. Cade, System Engineer for ITEL Corporation, contacted the Electronics Technology Laboratory (ETL) of Georgia Tech's Engineering Experiment Station for assistance in investigating the magnitude of the electromagnetic radiated and conducted environments in the vicinity of an ITEL Computer Processing Unit (CPU). This CPU is part of a new computer system installed by ITEL on the 21st floor of the Life of Georgia Building in Atlanta, Georgia. Computer personnel had been experiencing operational difficulties in the form of printed error messages during the running of programs. The susceptibility of the CPU to the ambient electromagnetic environments was suspected as the probable cause of these operational difficulties.

On 1 September 1977, ETL personnel performed preliminary measurements of the ambient radiated environment near the CPU. An analysis of the resulting data failed to provide any indication of ambient levels which were considered large enough to cause the operational difficulties. However, on the days following these preliminary measurements, the operational difficulties continued to occur. Consequently, ITEL requested that a more comprehensive survey of both the radiated and conducted environments be performed. In response to this request, a measurement program mutually agreeable to ITEL and ETL personnel was defined. The specific measurements were then conducted on the 8th and 9th of September.

Subsequent portions of this report identify the measurement locations, describe the test procedures and equipments used, and present the resulting data.

2. Measurement Program

2.1 Measurement Approach

In efforts to determine the types of measurements that should be made, two factors were considered: (1) the probable cause of the interference problems in the CPU and (2) previous experience in attempting to characterize electromagnetic environments in comparable facilities. When these factors were considered, it was decided that the following tasks would be performed:

- measure the radiated environment in the vicinity of the CPU;
- measure the conducted environment on CPU power and data cables, and
- continuously monitor the conducted environment during those time periods when the most frequent operational difficulties had arisen.

Both the radiated and conducted measurement locations were selected based on the recommendation of ITEL's engineers. Two series of these measurements were performed to characterize the daytime and nighttime environments. Also, based on ITEL's recommendations, appropriate time periods and specific signal and power cables were selected for continuous monitoring of the conducted environment.

2.2 Measurement Instrumentation

Because of its versatility, portability, wide frequency range, and availability of a visual display, the spectrum analyzer was chosen as the basic receiver for both radiated and conducted measurements. The actual spectrum analyzers used were Hewlett-Packard 8550 Systems with appropriate display and IF units. Various Hewlett-Packard RF plug-in units were used, depending on the frequency range being measured. During radiated tests, the spectrum analyzer was used with a complement of four different antenna types to cover the frequency range of 150 kHz to 2 GHz. The frequency range for the conducted test was 1 kHz to 110 MHz. For the conducted tests, the spectrum analyzers were used in conjunction with Fairchild Model PCL-25 Current Probes. During each test, the signal levels observed on the spectrum analyzer display were permanently recorded with a Hewlett-Packard Model 198A Scope Camera.

In addition to the spectrum analyzers, a Model 8100 Biomation transient recorder was used to continuously monitor one of the data cables during the selected time periods. This instrument stores the digital equivalent of the transient waveform in a memory. The digital representation is then used to reconstruct the analog signal at a slower time rate for display.

2.3 Measurement Procedures

2.3.1 Radiated Measurements

To perform the radiated measurements, the spectrum analyzer, the ancillary test equipment, and the applicable test antenna were interconnected as shown in Figure 1. The test antenna was initially disconnected to permit amplitude calibration of the spectrum analyzer. The antenna was then reconnected to the analyzer, and a measurement band consistent with the frequency range of the test antenna was selected. For each measurement band, the spectrum analyzer was tuned to the center frequency and the scan width was adjusted to display the entire band. Using an appropriate time base, the selected frequency was scanned while the analyzer display was observed. The antenna was then rotated in azimuth until the height of the signal display on the analyzer was maximized. This maximized display was then photographed using the scope camera.

This procedure was repeated for each of the thirteen frequency bands identified in Table I.

2.3.2 Conducted Measurements

The conducted measurement setup is shown in Figure 2. The conducted test setup is similar to the radiated setup except that a current probe is used as a pickup device instead of an antenna. To perform the measurements the analyzer was initially disconnected and calibrated in amplitude. With the input reconnected the analyzer was then tuned to the center frequency of the selected measurement band. The scan width was adjusted such that the total measurement band was displayed on the analyzer CRT. The current probe was then connected around the cable under test and the received signal observed on the analyzer display. This display was then photographed, and the procedure repeated for the next test cable.

3. Measurement Results

Typical photographic recordings which were made of the spectrum analyzer display during the radiated and conducted measurements are shown in Figures 3 and 4, respectively. To facilitate interpretation of the data, selected display amplitudes were extracted from the photographed displays. The signal

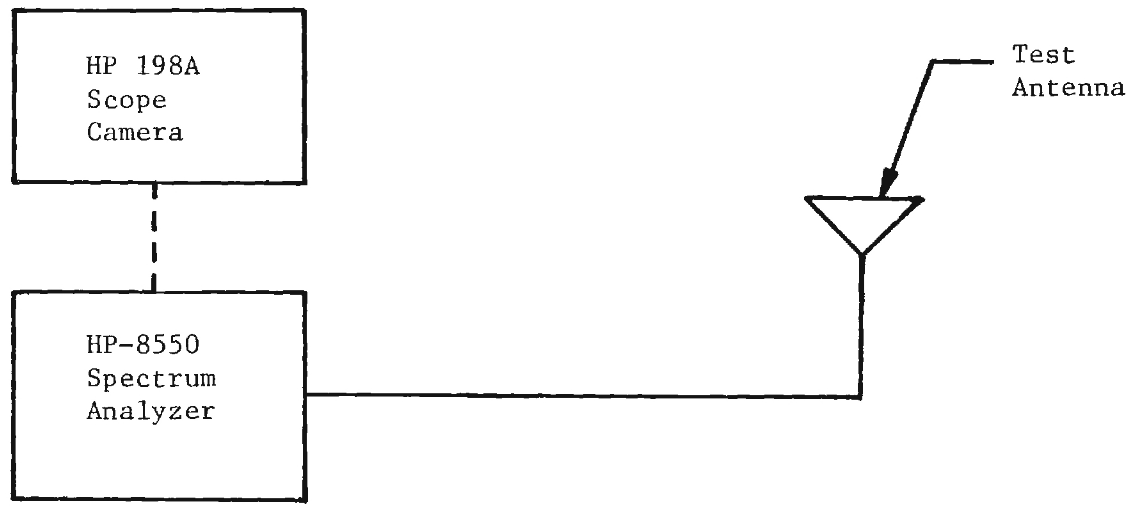


Figure 1. Test Configuration for Radiated Measurements.

TABLE I

RADIATED MEASUREMENT TEST EQUIPMENT AS A FUNCTION OF FREQUENCY BAND

Band	Frequency Range (MHz)	Test Equipment: Antennas	Test Equipment: Spectrum Analyzer* RF Unit
(A)	0.35 → 0.85	Singer LP-105 Loop	HP-8553
(B)	0.5 → 1.0	Singer LP-105 Loop	HP-8553
(C)	0.5 → 5.5	Singer LP-105 Loop	HP-8553
(D)	5 → 15	Singer LP-105 Loop	HP-8553
(E)	12 → 32	Singer LP-105 Loop	HP-8553
(F)	25 → 75	BIA-25 Biconical	HP-8553
(G)	60 → 110	BIA-25 Biconical	HP-8553
(H)	100 → 200	BIA-25 Biconical	HP-8554L
(I)	200 → 400	LCA-25 Log Conical	HP-8554L
(J)	400 → 600	LCA-25 Log Conical	HP-8554L
(K)	600 → 800	LCA-25 Log Conical	HP-8554L
(L)	800 → 1000	LCA-25 Log Conical	HP-8554L
(M)	1000 → 2000	ASN-113A Log Spiral	HP-8554A

*Display unit 141T and IF section 8552 used for all bands.

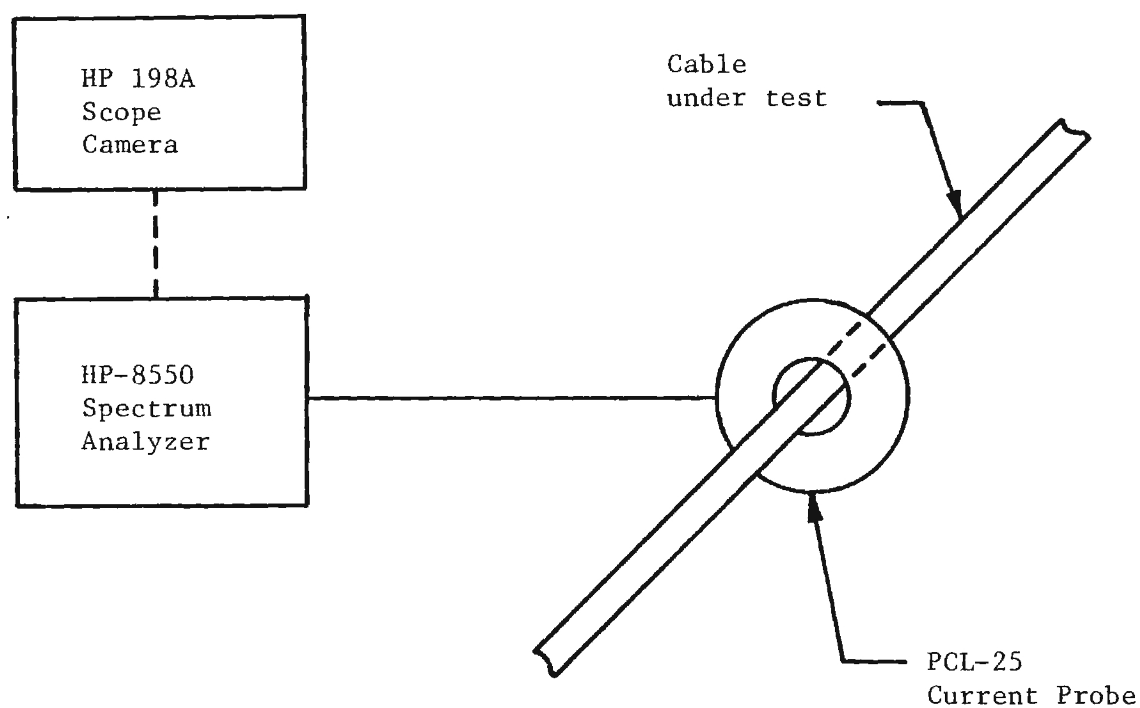
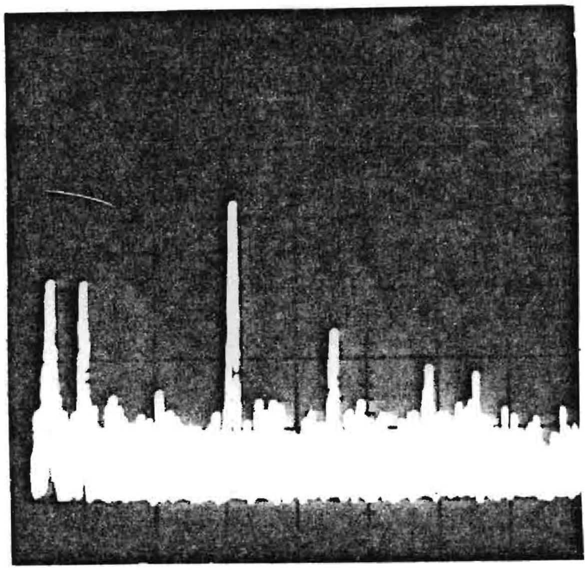


Figure 2. Test Configuration for Conducted Measurements.



Vertical Axis:

- Top Line = -50 dBm
- 10 dB/division

Horizontal Axis:

- 1.0 to 1.8 MHz
- 0.1 MHz/division

Vertical Axis:

- Top Line = 0 dBm
- 10 dB/division

Horizontal Axis:

- 70 to 110 MHz
- 5 MHz/division

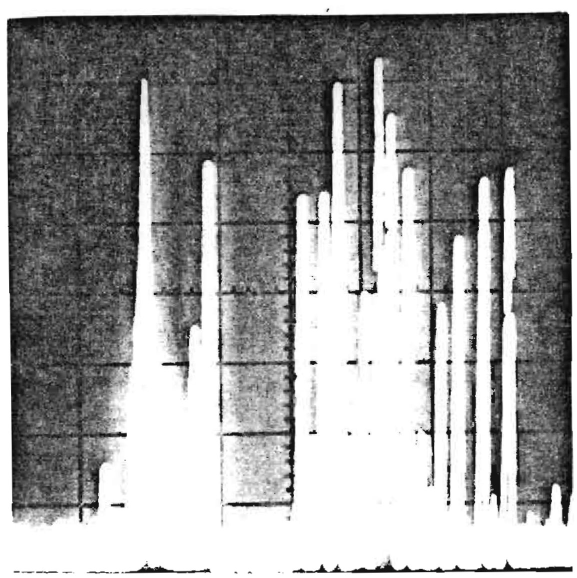
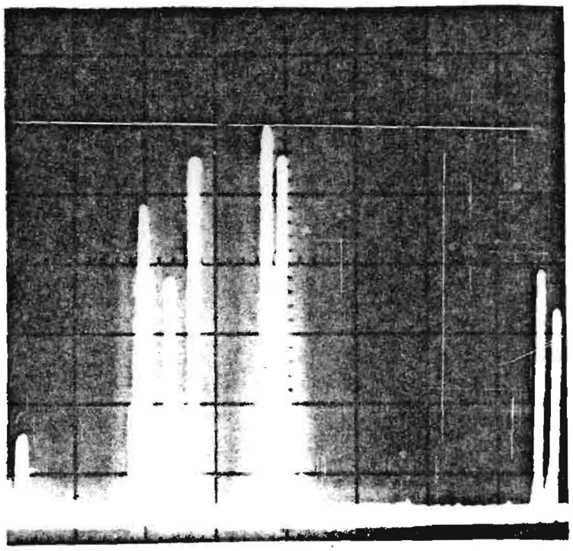


Figure 3. Photographs of Typical Spectrum Analyzer Displays for Radiated Emission Measurements.

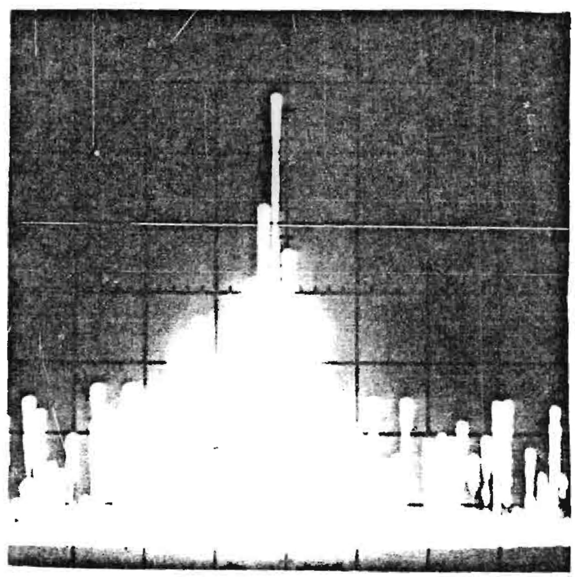


Vertical Axis:

- Top Line = 0 dBm
- 10 dB/division

Horizontal Axis:

- 420 to 580 MHz
- 20 MHz/division



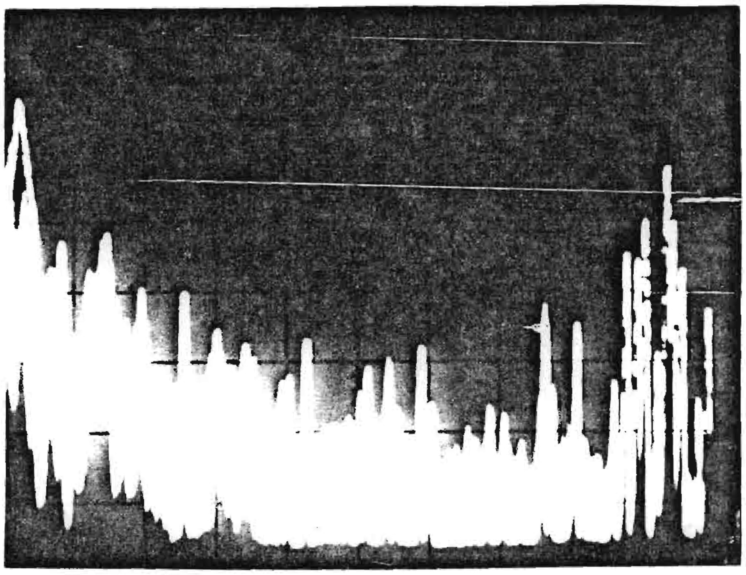
Vertical Axis:

- Top Line = 0 dBm
- 10 dB/division

Horizontal Axis:

- 1295 to 1335 MHz
- 5 MHz/division

Figure 3 (cont). Photographs of Typical Spectrum Analyzer Displays for Radiated Emission Measurements.



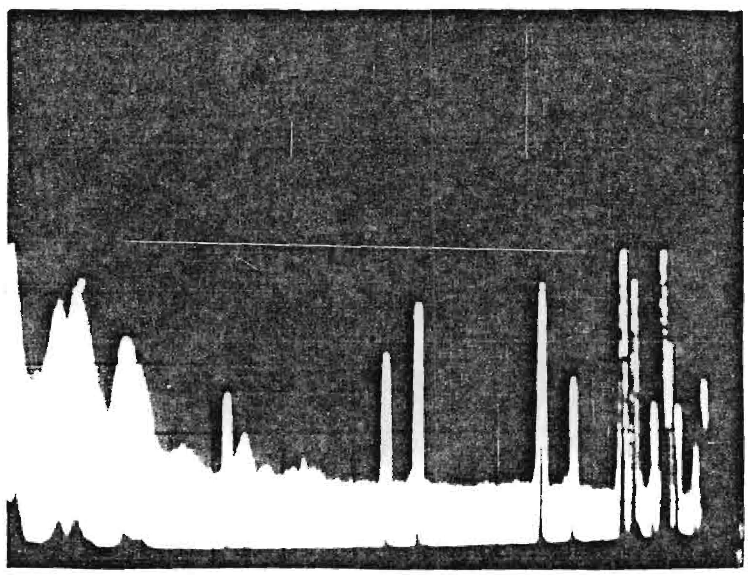
Vertical Axis:

- Top Line = -20 dBm
- 10 dB/division

Horizontal Axis:

- 0 to 100 MHz
- 10 MHz/division

a) Data Channel Cable



Vertical Axis:

- Top Line = -20 dBm
- 10 dB/division

Horizontal Axis:

- 0 to 100 MHz
- 10 MHz/division

b) Power Line Cable

Figure 4. Photographs of Typical Spectrum Analyzer Displays for Conducted Measurements on a Data Channel Cable and a Power Line Cable.

levels were converted to units of field intensity or conducted current level and tabulated. The following equations were used to convert the spectrum analyzer display data to appropriate units:

(a) Radiated Emissions*:

Narrowband Emissions (dBμV/m) = Spectrum analyzer display amplitude (dBm) + K_1 + AF (dB),

where K_1 = 107 dB, a constant that converts the spectrum analyzer display from dBm to dBμV, and AF is the antenna factor for converting dBμV to dBμV/m for the particular antenna in use over a specific frequency range. The antenna factor for each test antenna is given in the Appendix.

(b) Conducted Emissions:

Narrowband Emissions (dBμA) = Spectrum analyzer display amplitude (dBm) + K_1 + CPF (dB), and

Broadband Emissions (dBμA/MHz) = Spectrum analyzer display amplitude (dBm) + K_1 + CPF (dB) + K_2,

where K_1 = 107 dB as above, CPF is the current probe factor that converts the spectrum analyzer display from dBμV to dBμA, and K_2 is a factor that converts the spectrum analyzer measurement bandwidth to a standard reference bandwidth of 1.0 MHz. A graphical presentation of the current probe factor as a function of frequency and a tabulation of the bandwidth factors are also given in the Appendix.

3.1 Radiated Environment

The radiated environment in the vicinity of the CPU was measured over the frequency range of 350 kHz to 2 GHz with the appropriate test antenna positioned between the CPU and the north wall of the building. The measurements were performed between 3:00 p.m. and 6:00 p.m. on 8 September 1977 and between 4:00 a.m. and 6:00 a.m. on 9 September 1977. The measured levels were essentially the same during the two time periods. The major differences noted were due to the non-operational status of some broadcast stations and the reduced power of others during the early morning time period. The maximum measured levels are identified in Tables II through V. As shown in Table V, the maximum measured radiated level of 3.5 volts per meter at

*During the surveys no radiated broadband emissions of significant magnitudes were noted.

TABLE II

RADIATED ENVIRONMENT AT TEST SITE--AM COMMERCIAL BROADCAST STATIONS

Station	Frequency (MHz)	Measured RF Field Intensity (Volts/meter)	Measured RF Field Intensity (dBμV/m)
WPLO	.590	0.013	82
WRNG	.680	0.009	79
WSB	.750	0.003	68
WQXI	.790	0.004	72
WXAP	.860	0.005	73
WGST	.920	0.004	72
WGUN	1.010	0.014	83
WXLL	1.310	0.006	76

TABLE III

RADIATED ENVIRONMENT AT TEST SITE--FM
COMMERCIAL BROADCAST STATIONS

Station	Frequency (MHz)	Measured RF Field Intensity (Volts/meter)	(dB/μVm)
WRSA	88.5	0.05	94
WABE	90.1	0.05	94
WREK	91.1	0.3	110
WQXI	94.1	0.5	114
WPCH	94.9	0.2	106
WKLS	96.1	0.07	97
WSB	98.5	0.008	78
WLTA	99.7	0.02	87
WBIE	101.5	0.06	96
WVEE	103.3	0.08	98

TABLE IV

RADIATED ENVIRONMENT AT TEST SITE--TV
COMMERCIAL BROADCAST STATIONS

Channel	Function	Frequency (MHz)	Measured RF Field Intensity (Volts/meter)	(dBμV/m)
2	Video	55.25	0.039	92
	Audio	59.75	0.028	89
5	Video	77.25	0.018	105
	Audio	81.75	0.044	93
8	Video	181.25	0.009	79
	Audio	185.75	0.003	69
11	Video	199.25	0.022	87
	Audio	203.75	0.012	82
17	Video	489.25	0.22	107
	Audio	493.75	0.14	103
30	Video	567.25	0.025	88
	Audio	571.75	0.013	82
46	Video	663.25	0.063	96
	Audio	667.75	0.02	86

TABLE V

RADIATED ENVIRONMENT AT TEST SITE--
MISCELLANEOUS SIGNALS

Identification	Frequency (MHz)	Measured RF Field Intensity (Volts/meter)	(dBμV/m)
Fixed Mobile	2.6	0.004	72
Fixed Mobile	35	0.007	77
Fixed Mobile	46	0.002	65
Fixed Mobile	155	0.05	94
Fixed Mobile	460	0.07	97
Fixed Mobile	470	0.11	101
FAA Air Route Surveillance Radar in Smyrna, Georgia	1315	3.5	131

1.315 GHz was determined to be produced by the FAA Air Route Surveillance Radar in Smyrna, Georgia. All of the other radiated levels were at least 17 dB lower.

3.2 Conducted Environment

Conducted noise current levels were measured over the frequency range of 1 kHz to 110 MHz on the filtered side of the power conductors feeding the CPU and on CPU-associated interconnecting data cables. These measurements were performed during the same time periods identified for the radiated measurements. With corresponding differences as noted for the radiated environment, the conducted current levels were essentially the same during the two time periods. The maximum measured broadband and narrow-band levels are listed in Table VI. The maximum broadband signal occurred on the Data Channel #4 Tag cable and had a value of 3500 μa/MHz. The narrow-band signals presented in Table VI correspond in frequency to the local FM broadcast stations. The maximum measured level of 560 μa occurred on Data Channel #4 Tag cable.

As previously noted, continuous monitoring of the conducted current levels on one power cable and two signal cables were performed during selected time periods. No significant variations or transients in the measured levels were noted on any of the cables.

4. Conclusions

Based on these results, the following conclusions can be drawn:

(a) At its present location, the CPU will have to operate in an environment having a peak level of at least 14 millivolts per meter in the 600 to 1600 kHz AM band, 500 millivolts per meter in the 88 to 108 MHz FM band, 220 millivolts per meter in the 50 to 670 MHz television band, and 3.5 volts per meter at 1315 MHz. It should be noted that these levels are applicable for the specific conditions under which the measurements were made. Under different conditions, i.e., propagation variations, antenna location, new construction in area, etc., these intensities could vary considerably.

TABLE VI

CONDUCTED EMISSIONS ON SELECTED CPU CABLES

Measurement Location	Maximum Recorded Emissions			
	Broadband		Narrowband	
	(dBμa/MHz)	(μa/MHz)	(dBμa)	(μa)
Power Cable #1	48	250	44	150
Power Cable #2	39	89	47	220
Data Channel #0 Tag Cable	64	1500	54	500
Data Channel #1 Tag Cable	65	1700	44	150
Data Channel #2 Tag Cable	56	630	52	390
Data Channel #3 Tag Cable	46	200	54	500
Data Channel #4 Tag Cable	71	3500	55	560

(b) In its present condition, the CPU is operating with broadband and narrowband noise current levels on the order of approximately 250 μa/MHz and 220 μa, respectively, on its input power cabling. Similarly, maximum current levels of 3500 μa/MHz and 560 μa exist on the Data Channel Tag cables.

APPENDIX

This appendix presents the various antenna, current probe, and bandwidth factors used in converting the measured signal levels to appropriate units for analyses.

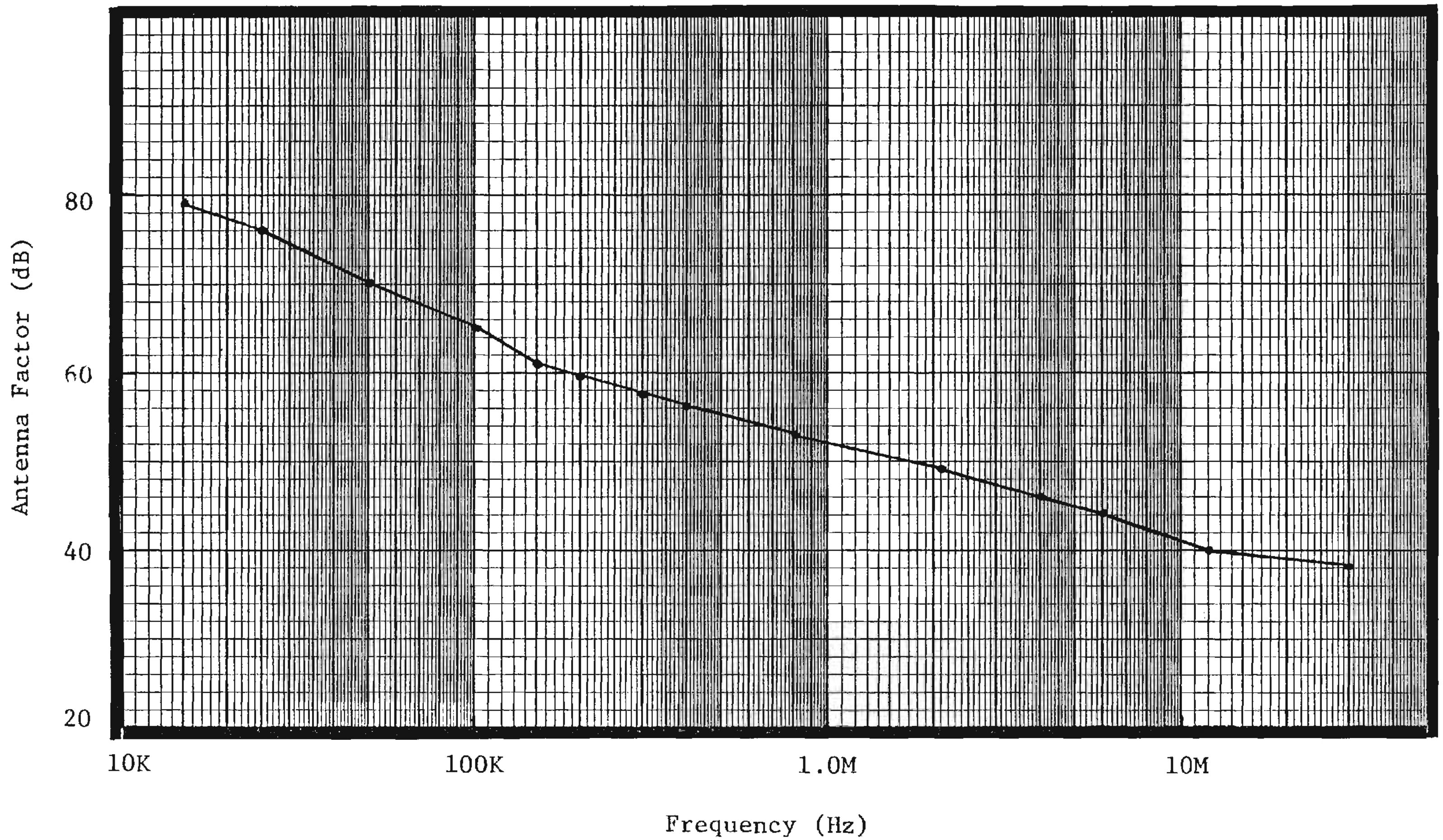


Figure A-1. Antenna Factor for the Singer Model LP-105 Loop Antenna.

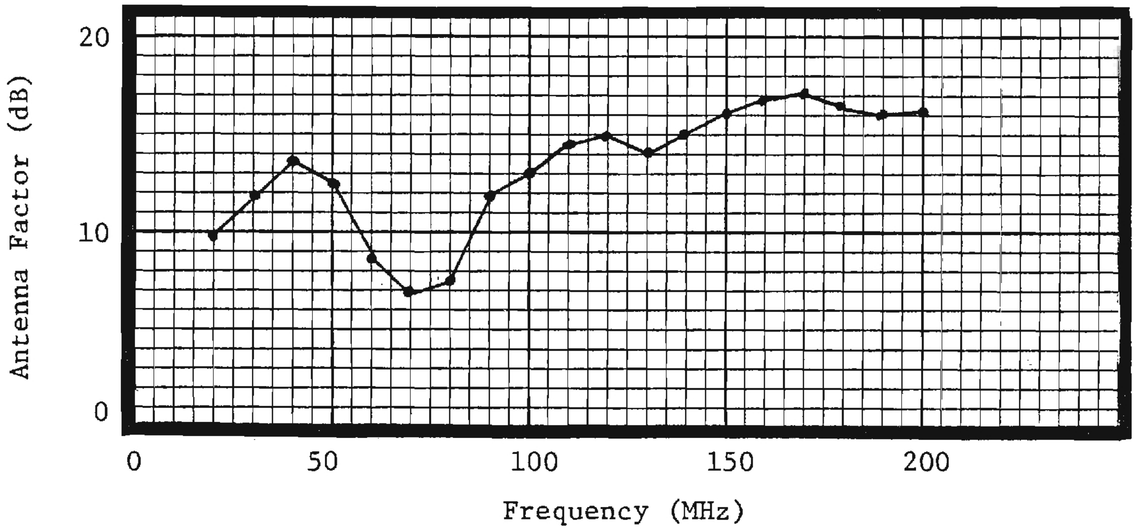


Figure A-2. Antenna Factor for the Electro-Metrics Model BIA-25 Biconical Antenna.

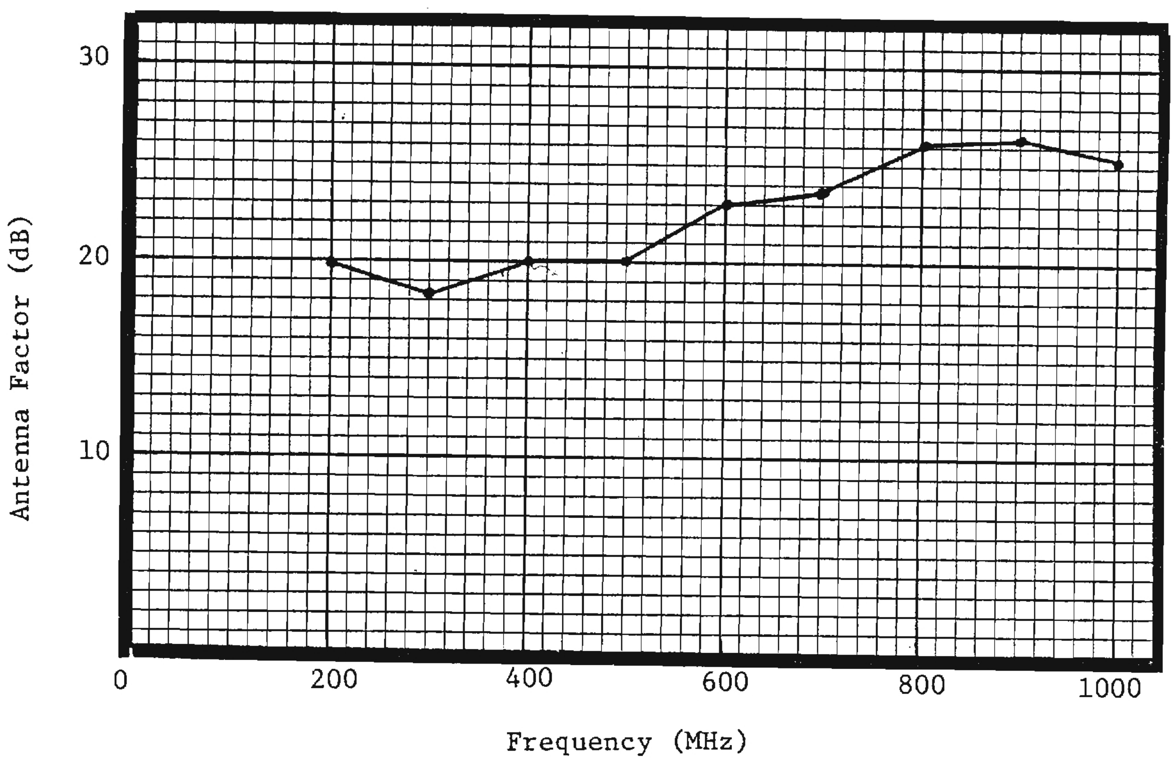


Figure A-3. Antenna Factor for the Electo-Metrics Model LCA-25 Log Conical Antenna.

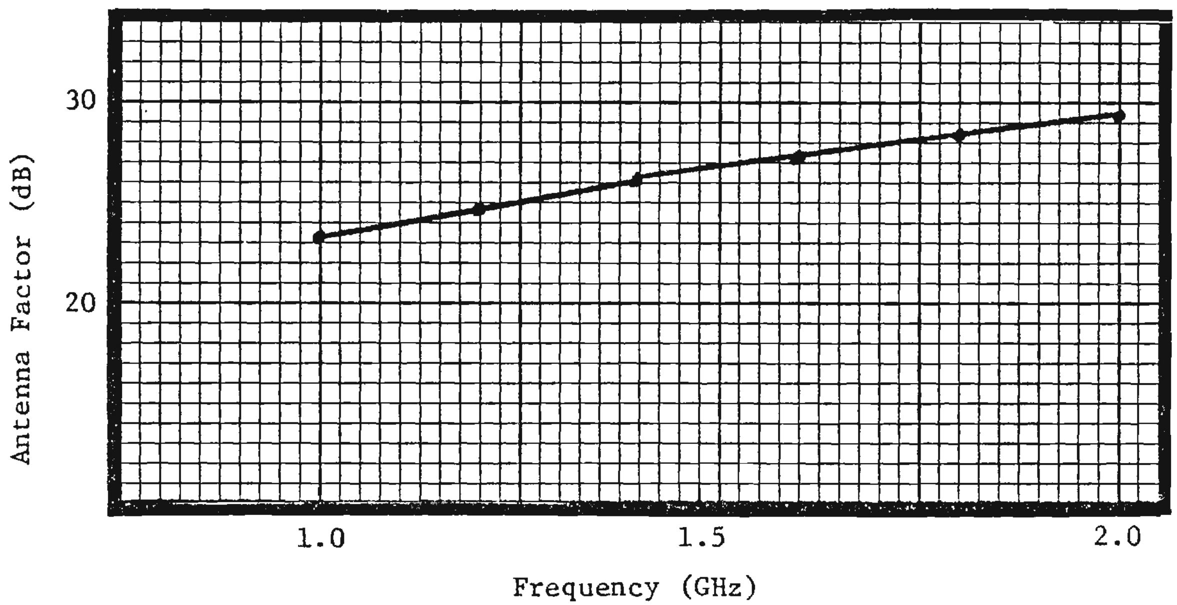


Figure A-4. Antenna Factor for the AEL Model ASN-113A Cavity-Backed Spiral Antenna.

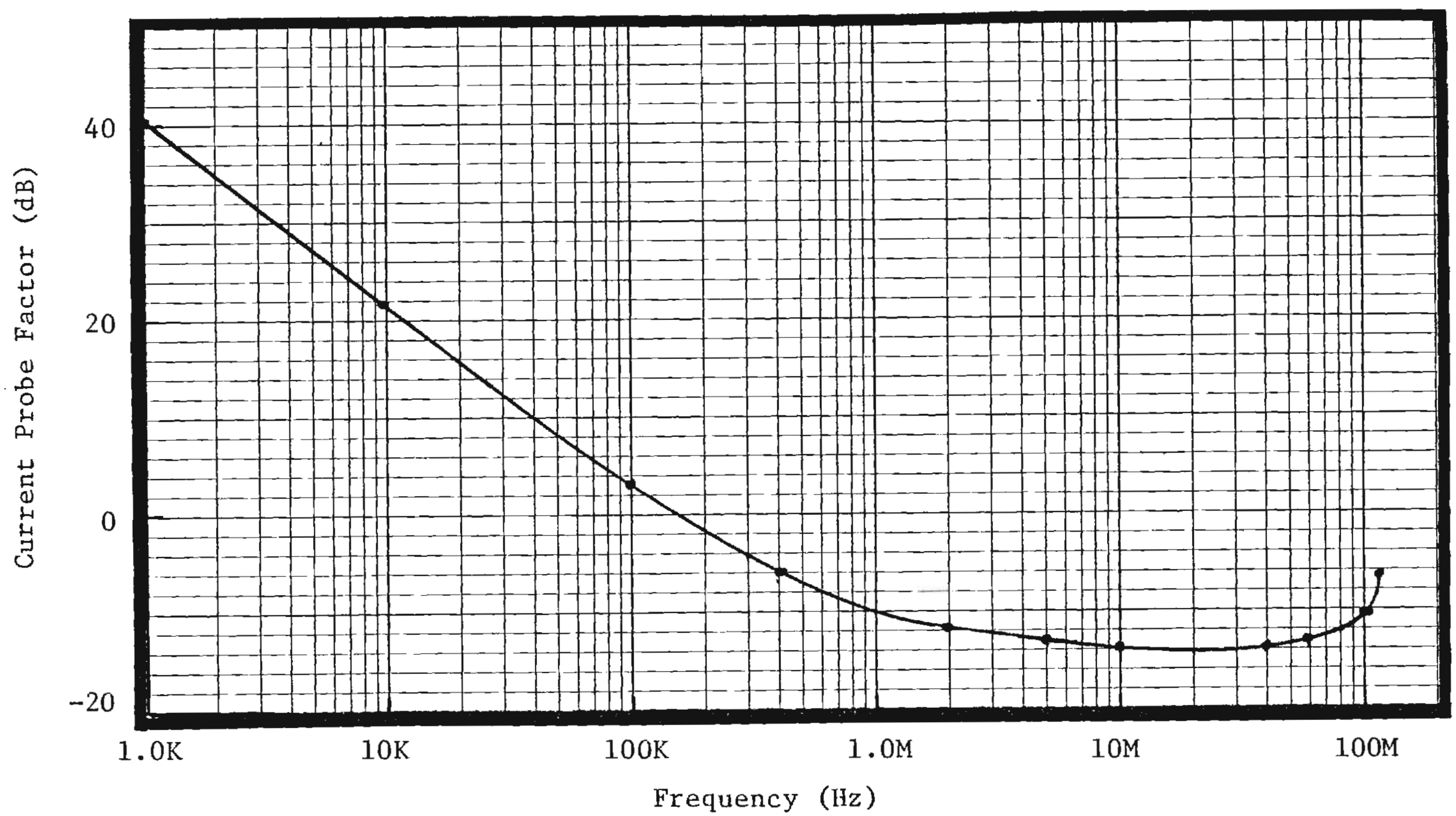


Figure A-5. Current Probe Factor for the Electro-Metrics Model PCL-25 Current Probe.

TABLE A-1

SPECTRUM ANALYZER BANDWIDTH FACTOR

Measurement Bandwidth (kHz)	1.0 MHz Conversion Factor (dB)
0.3	67
1.0	57
3.0	47
10.0	37
30.0	27
100.0	17
300.0	9